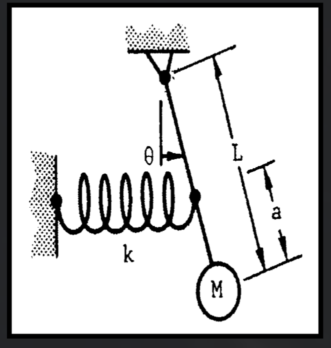
Modal Assessment of Inertial Load Simulator

Goals

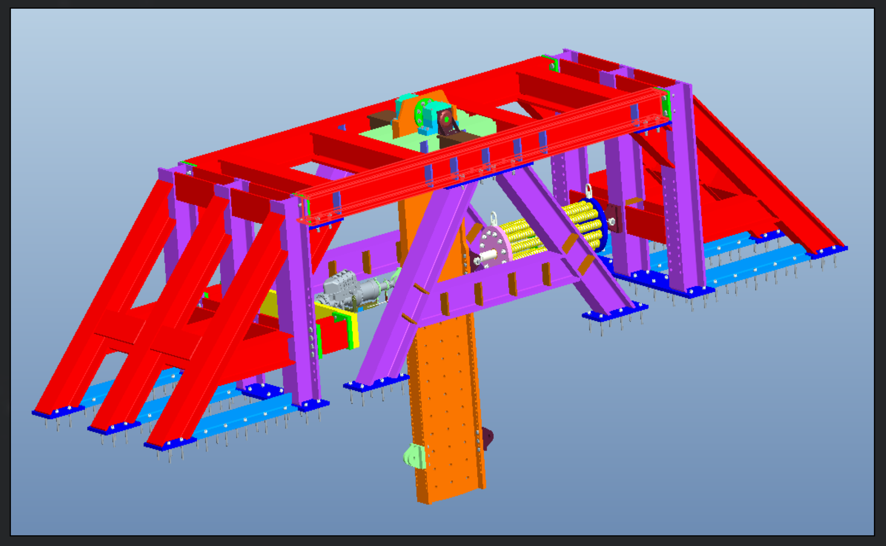
- Perform modal assessment of two ILS in the TVC Test Facility at MSFC.
- Use both Hydraulic and Electro-hydrostatic Actuators to excite ILS frames.
- Analyze and archive data for future use by ER35.

Methodology

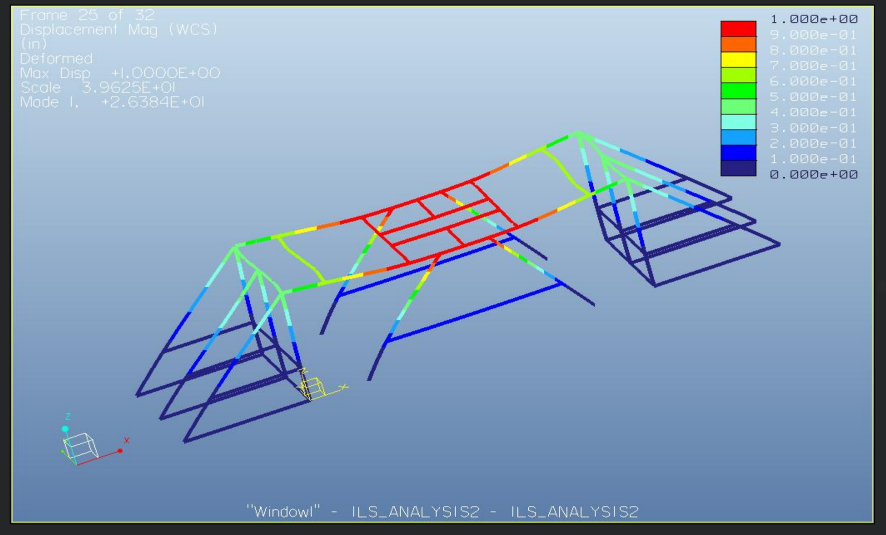
- Modal analysis is the dynamic study of structures to determine their inherent natural frequencies.
- Natural frequencies are the frequencies at which an object or system vibrates when struck by an impulse or driving force. This frequency is governed by the system mass and stiffness.
- Pendulum and back plate assembly
  - $f_N = \frac{1}{2\pi}\left(\frac{ka^2}{ML^2}+\frac{g}{L}\right)^{1/2}$
  - $f_N = 2.75$ Hz



- Computational Model
  - Pro-Mechanica was used to build a wire-frame modal of the ILS. These wires each were defined with a cross-section that correlated to the cross-section of the beam it represented.
  - This model was used to predict the natural frequencies of the structure.
  - First mode predicted to be approximately 26 Hz out of pendulum plane



ILS CAD Model



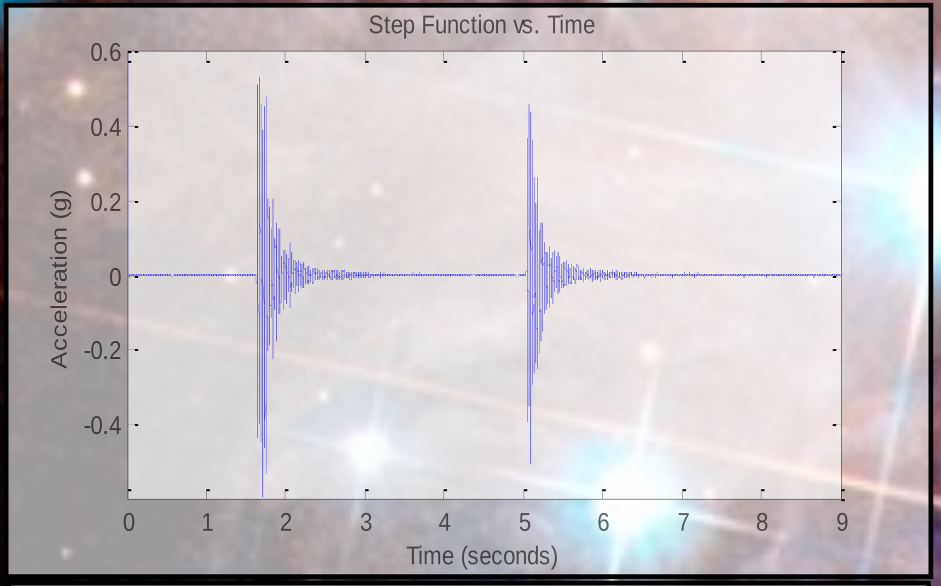
First Mode of ILS-Approximately 26 Hz

Intro and Background

Thrust Vector Control (TVC) is a means of directing the thrust from a rocket nozzle in order to control a vehicle. Traditionally, TVC is accomplished by means of two actuators mounted 90° apart that push and pull on the nozzle; gimballing the engine on two axes. During design, actuators are tested on an Inertial Load Simulator (ILS), which is a large pendulum, mounted on a stiff frame, that represents the inertial load of the engine. Marshall Space Flight Center (MSFC) recently fabricated two new ILS frames. Our project was to characterize the dynamic response of these frames while the pendulum is in motion. This is vital information about the capabilities of the TVC test lab.

Results

- MatLab was used to filter, shift, then analyze the data obtained from accelerometers and load cells.
- Fast Fourier Transforms (FFT) were used to obtain the frequency response functions from data readings
- Frequency response functions indicate at what frequencies mode shapes occur.



Accelerometer readings from a 0.8 in. step and return to null

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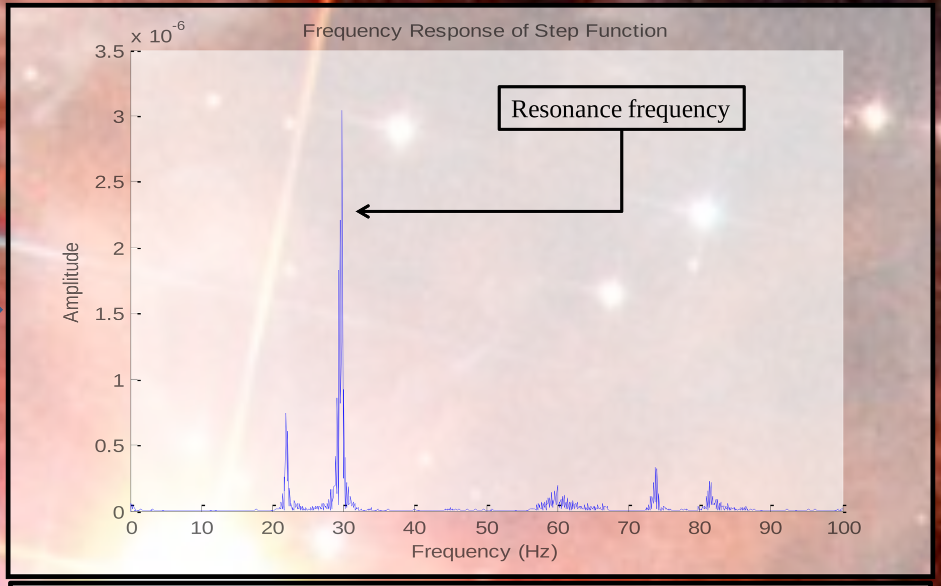
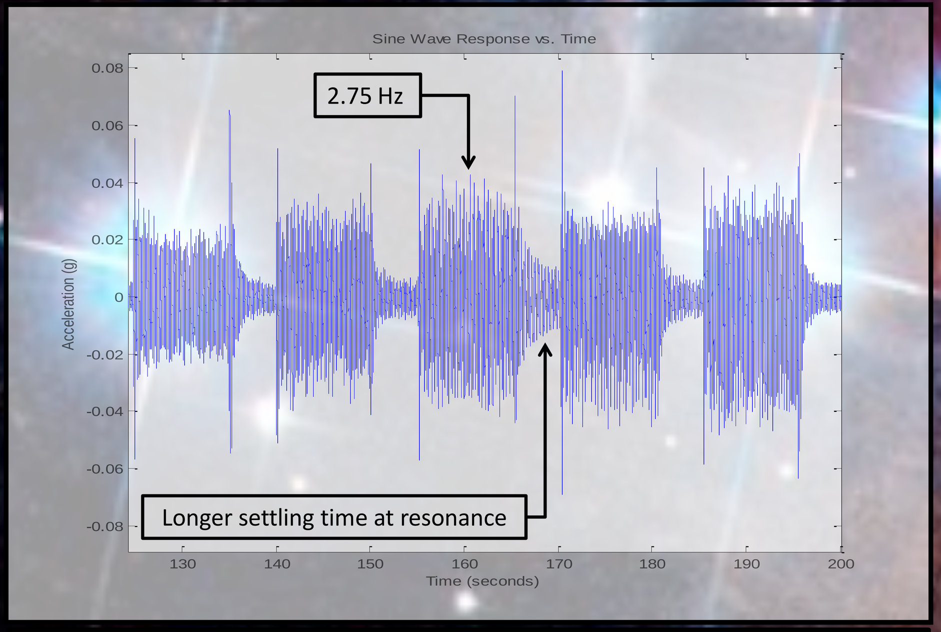


FFT of step function taken in the east/west direction



Sine forcing function showing resonance at 2.75 Hz on pendulum

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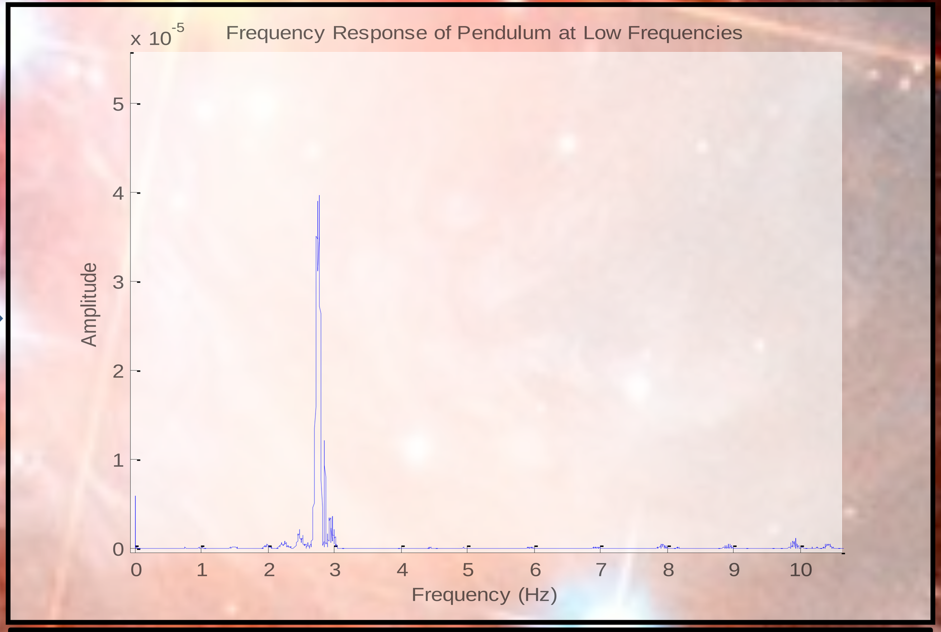


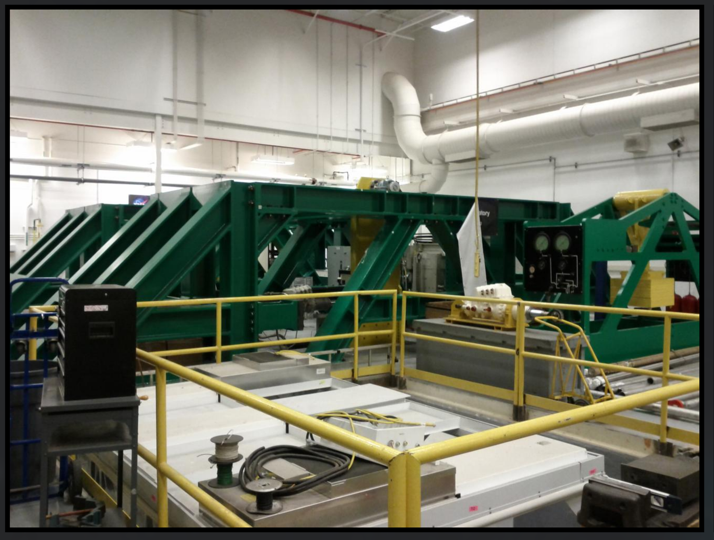
FFT of sine forcing function with resonance at 2.75 Hz on pendulum

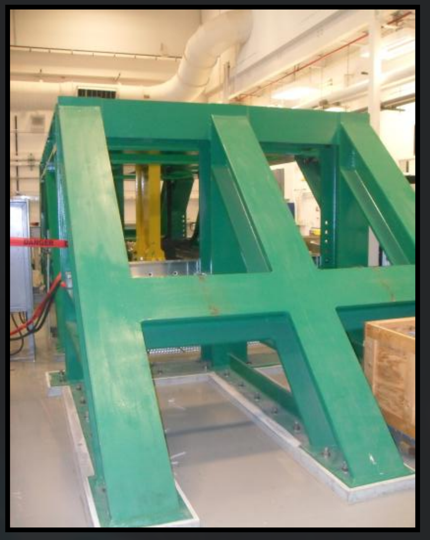
Conclusion/Further Research

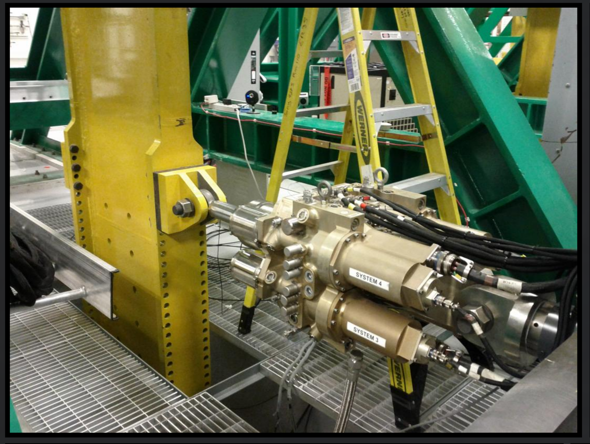
- Impulse and Hammer FFTs in the out of plane direction for both ILS show the first major mode to be around 22 Hz.
  - This is roughly consistent with the Pro-Mechanica model predictions.
- First mode well above the operating frequency of the actuators (11 Hz).
- Impulse hammer and step function showed similar results at the lower frequencies.
- Longitudinal results showed no resonance below 60 Hz due to stiffness of the design.
- Resonance at 2.75 Hz was seen on the pendulum in both time and frequency domain
  - Increased settling times were seen at the 2.75 Hz driving function in the time domain.
  - Single dominant peak below 10 Hz seen at 2.75 Hz in frequency domain.
- Further testing on the Hydraulic system with constant amplitude.

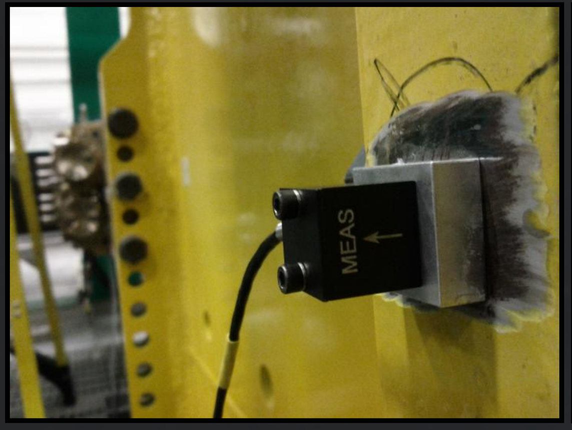
Procedures

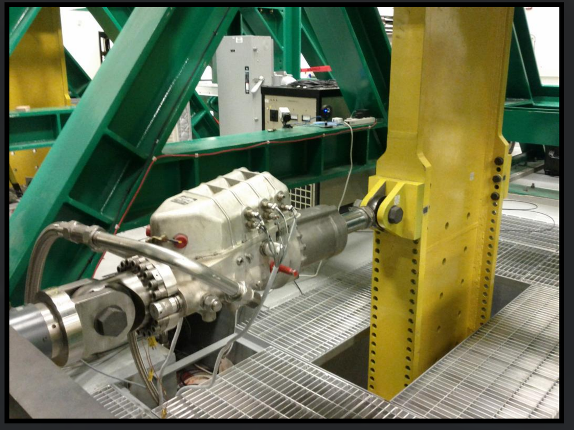
- Five 3-axis and five single-axis accelerometer mounting blocks were fabricated
- Positions were chosen based on results from the Pro-Mechanica model
- Accelerometer blocks and accelerometers were mounted to the ILS frame
- ILS frame was excited using sine wave forcing functions, step functions, and hammer impulses
- Data was recorded at 10,000 Hz using Lab View











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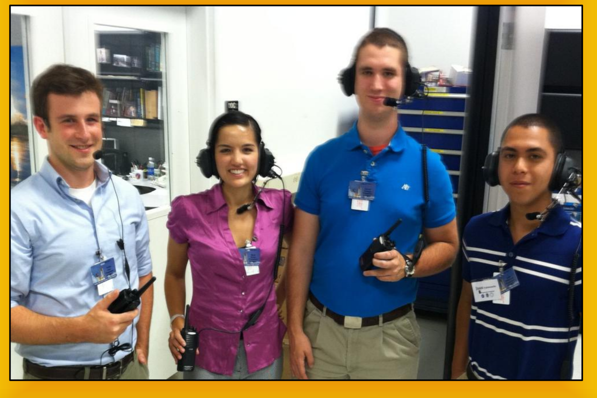

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